ADMINISTRATIVE INFORMATION

1. **Project Name:** Development of Cost Effective Ceramic and Refractory Components for AL Melting and Casting.

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2. **Lead Organization:**
Pyrotek, Inc.
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3. **Principal Investigator:**
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4. **Project Partners:**
Oak Ridge National Laboratory – Ronald Ott, 865-574-5172
University of Missouri – Rolla – Jeff Smith, 573-341-4447

5. **Date Project Initiated:** August 1, 2002; FY 2003

6. **Expected Completion Date:** July 2005

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:**

   The primary goal is to develop glazes for sealing surface porosity in thermal shock-resistant fused silica refractories used for low-pressure casting of aluminum. The focus of this project is to develop and validate new classes of cost-effective low-permeability ceramic and refractory components for handling molten aluminum in both smelting and casting environments. The primary goal is to develop materials and methods for sealing surface porosity in thermal shock-resistant ceramic refractories used in the low-pressure casting of aluminum.

8. **Technical Barrier(s) Being Addressed:**

   Products currently used in this application have a very limited lifespan. This creates inefficiency because of increased scrap and downtime. Also, the low coefficient of thermal expansion of dense fused silica makes it difficult to develop a glaze with a CTE to match.

9. **Project Pathway:**

   Two methods are being approached to alleviate this problem. Work is being undertaken to develop a glaze that can be applied to dense fused silica that will both seal the surface and prevent reaction between the molten aluminum and dense fused silica. As a separate task, the particle size distribution of standard refractories is being adjusted to achieve a pressure tight matrix. On this same path, work is being undertaken to develop a coating for standard refractories that will seal the surface.

10. **Critical Technical Metrics:**

Baseline Metrics:

- Current DFS stalk tubes last a week uncoated
- Operating temperature of 700°C (1300°F)
- Need to reduce the permeability problem
- Need to eliminate the reaction between DFS and molten aluminum
- DFS has an extremely low coefficient of thermal expansion (CTE) of 0.5×10^{-6}/°C
- Standard refractories cannot maintain gas pressure (15 PSI) in this application

Project Metrics:

- Increase life of stalk tube to 5 or 6 weeks
- Introduce a glaze to reduce gas penetration at a reasonable cost. (for both DFS and standard refractories).
- Glaze must be compatible with molten aluminum and have a low CTE to match that of DFS
- Optimize particle size distribution to develop a standard refractory that will be pressure tight.

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:**

ID Number	Task / Milestone Description	Planned Completion	Actual Completion	Comments
1	**Development of surface treatments (autogenous coatings) to seal the surface of porous fused silica**	09/30/03	Pending	On-going
1.1	Characterize silica refectories supplied by Pyrotek with regard to microstructure, macrostructure, and functional properties, such as permeability and wetting characteristics with respect to molten aluminum.	12/31/02	2/31/03	
1.2	Determine current particle size distribution of aggregate and optimize to obtain a continuous distribution to minimize permeability.	02/28/03	1/15/04	
1.3	Determine cost-effective methods(s) for applying coatings to Pyrotek refractories.	02/28/03	2/28/03	3 methods identified
1.4	Determine coating formulations.	02/28/03	2/28/03	6 formulations identified
1.5	Apply experimental coatings to test coupons machined from Pyrotek materials and densify in resistance furnace or high-density infrared heating system.	09/30/2003	1/15/04	Not Cost Effective
1.6	Evaluate microstructure,	09/30/2003	Pending	

	macrostructure, and functional properties, such as permeability and wetting characteristics with respect to molten aluminum, of coated samples.			
2	**Advanced Ceramic Coatings**			
2.1	Determine coating formulations.	4/30/03	Pending	Moved out pending results from above
2.2	Apply coatings to Pyrotek's silica and mullite refractories using techniques developed in Task 1.	05/31/2003	"	"
2.3	Sinter coatings using resistance furnace and/or high-density infrared heating.	08/31/2003	"	Pending previous actions

- Milestone (1.1): Characterizations have been done on existing materials with an emphasis on existing structures and properties. It has been determined that there is no significant difference in the microstructure running the length of the component. The microstructure consists of approximately 65% area fraction of dense SiO_2 particles that are on the order of 200 µm in length, while the remaining 35% area fraction consist of loosely packed small particles ranging from 5 µm on down in size. Coating materials have been identified, sorted and prepared for application to existing substrates.
- Milestone (1.5, 1.6): Several semicrystalline glazes have been selected and applied to test specimens of fused silica. Preliminary results show that the glazes are crystalline and adherent to the fused silica.
- Milestone (1.5): The semicrystalline glazes have been chosen in order to best match the coefficient of thermal expansion (CTE) of fused silica, $05.x10^{-6}$/°C. With such a low CTE it is difficult to obtain a glaze that will match and not react with molten aluminum. The semicrystalline glazes seem to suit the need.
- Milestone (1.1): A full scale permeability measuring apparatus has been developed in order to accommodate complete fused silica down tubes and is currently being refined in order to be used as a quality control apparatus.
- Milestone (1.2): Preliminary particle size distribution analysis has been performed on several existing blends and has shown that there may be a need to refine the distribution in order to minimize the permeability.
- Milestone (1.2): More data is being gathered on particle size distribution of raw materials so that the deficiencies in size ranges are minimized.
- Milestone (1.4): Several methods for applying the glazes have been investigated, and those include dipping, spraying and brushing. The most cost effective method would be dip coating, which also applies the most uniform thickness.
- Milestone (1.5): Economic feasibility of High Density Infrared heating has been discussed and has shown that it can be used to fuse the surface of the fused silica but might be cost limiting.

12. **Future Plans:**

ID Number	Task / Milestone Description	Planned Completion	Actual Completion	Comments
1	**Development of surface treatments (autogenous coatings) to seal the surface of porous fused silica**	09/30/03	Pending	
1.1	Refine selected coatings and determine suitability for intended use	5/31/03	"	
1.2	Apply suitable coatings to full scale parts	6/30/03	"	
1.3	Evaluate properties of coated samples	6/15/03	"	
1.4	Refine particle size distribution for castable refractory blend.	6/30/03	"	
2	**Advanced Ceramic Coatings**		"	
2.1	Determine coating formulations.	4/30/03	"	
2.2	Apply coatings to Pyrotek's silica and mullite refractories using techniques developed in Task 1.	05/31/2003	"	
2.3	Sinter coatings using resistance furnace and/or high-density infrared heating.	08/31/2003	"	
2.4	Evaluate microstructure, macrostructure, and functional properties, such as permeability and wetting characteristics with respect to molten aluminum, of coated samples.	03/31/2004	"	
3	**Coat and Field Test Prototype Components**		"	
3.1	ORNL will scale up the previously developed coating processes.	11/30/2003	"	
3.2	ORNL will apply autogenous and advanced mixed-oxide coatings to Pyrotek-supplied prototype components.	03/31/2004	"	
3.3	ORNL will sinter coatings on selected components using high-density infrared heating.	04/30/2004	"	
3.4	Pyrotek will sinter coatings on selected components using resistance furnace heating.	04/30/2004	"	
3.5	Pyrotek will field test the coated components at an aluminum casting shop.	06/30/2004	"	
3.6	Both ORNL and Pyrotek will evaluate the tested components.	09/30/2004	"	

13. **Project Changes:**

    Pyrotek is undergoing a Corporate restructuring and this has caused some delays in the project. A one-year, no-cost extension has been applied for.

14. **Commercialization Potential, Plans, and Activities:**

    Upon completion of testing, Pyrotek will introduce developments to the market through normal sales channels, and will test the new technology at an aluminum casting facility.

15. **Patents, Publications, Presentations: N/A**